REMARKS

Claims 1, 4, and 6 to 16, as amended, appear in this application for the Examiner's review and consideration. Claims 13 to 16 have been withdrawn, as being directed to a non-elected invention. The amendments are fully supported by the specification and claims as originally filed. Therefore, there is no issue of new matter. In addition, the amendments to the independent claims add recitations that elaborate on the structure of the presently claimed invention, and, thus, do not affect the scope of the claims. The amendments only further clarify the claimed invention.

Claim 11 stands rejected under 35 U.S.C. § 112, first paragraph, for the reasons set forth on page 2 of the Office Action. In response, Applicant submits that claim 11, as amended, recites the method of the invention, where the method is repeated until a thermal conductivity of the fuel arrangement is increased about 50 percent for a 10 percent volume loading of the second phase compared to that of a fuel arrangement formed from conventional uranium dioxide. The amendment of claim 11 is fully supported by the present specification, at page 6, lines 3 and 4. Thus, claim 11, as amended, recites a specific increase in thermal conductivity for a specific loading of the second phase.

It should be noted that, those skilled in the art will understand that the increase in thermal conductivity of the fuel relative to that of a fuel arrangement formed from conventional uranium dioxide can be varied with the presently claimed method. Increasing the loading of the second phase may increase the thermal conductivity further, depending on the thermal conductivity of the second phase. The combined thermal conductivities of the second phase, the uranium dioxide, and any other components in the arrangement will determine the thermal conductivity of the fuel, but there is an upper limit to the increase in thermal conductivity that can be obtained by increasing the loading of the second phase.

Similarly, a reduction in the loading of the second phase in the porous uranium dioxide will typically result in a reduction in the thermal conductivity of the fuel relative to a higher loading of the second phase. Those skilled in the art will understand that the reduction will not be obtained where the original loading of the second phase is too small to be significant or is significantly larger than that required to provide the upper limit for the thermal conductivity of the fuel. Where the original loading is significantly larger than that required to provide the upper limit for the thermal conductivity of the fuel, a relatively

large reduction in the loading may be required to obtain the desired reduction in the thermal conductivity of the fuel provided by the presently claimed invention.

Thus, those skilled in the art will understand that the scope of claim 11, as amended, does not encompass an unlimited increase in thermal conductivity.

Therefore, as an unlimited increase in the thermal conductivity is not within the scope of claim 11, the claims are fully enabled by the specification. Accordingly, it is respectfully requested that the Examiner withdraw the rejection of claim 11 under 35 U.S.C. § 112, first paragraph.

Claims 1, 4, 6 to 9, 11, and 12 stand rejected under 35 U.S.C. § 103(a), as being unpatentable over British Patent Publication No. 1,035,789 (GB'789) in view of U.S. Patent No. 3,164,487 to Carley-Macauly et al. (Carley-Macauly), for the reasons set forth on page 3 of the Office Action;

Claims 1, 4, 6 to 9, 11, and 12 stand rejected under 35 U.S.C. § 103(a), as being unpatentable over Carley-Macauly in view of U.S. Patent No. 3,305,325 to Nicholson et al. (Nicholson) and U.S. Patent No. 4,073,834 to Mysels, for the reasons set forth on page 4 of the Office Action;

Claims 2 and 10 stand rejected under 35 U.S.C. § 103(a), as being unpatentable over GB'789 in view of Carley-Macauly or Carley-Macauly in view of Nicholson and Mysels, and further in view of U.S. Patent No. 3,129,141 to Burnham et al. (Burnham) and U.S. Patent No. 5,952,046 to Chayka, for the reasons set forth on page 4 of the Office Action; and

Claim 11 stands rejected under 35 U.S.C. § 103(a), as being unpatentable over Carley-Macauly in view of Nicholson and Mysels, and further in view of GB'789, for the reasons set forth on page 4 of the Office Action.

In response, Applicant submits that the presently claimed invention is directed to a method to produce uranium dioxide fuel in pellet shape for use in a light water reactor. The presently claimed method comprises providing an arrangement, comprising porous uranium dioxide, infiltrating the porous uranium dioxide with a precursor liquid, then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, and thermally firing the arrangement, comprising the porous uranium dioxide, such that the precursor liquid is converted to a second phase.

Therefore, to be within the scope of the present claims, the prior art must disclose or suggest infiltrating porous uranium dioxide with a precursor liquid and then curing the arrangement that comprises the porous uranium dioxide infiltrated with the precursor

liquid. The disclosed method must also disclose or suggest that the method provides uranium dioxide fuel in pellet shape for use in a light water reactor.

Support for the recitation in claim 1, as amended, of an arrangement, comprising porous uranium dioxide can be found in the present specification at page 3, line 34, to page 4, line 3, where the present specification teaches

> The porous matrix of the uranium dioxide arrangement 10 can be formed, for example, by pressing uranium dioxide powder into a "green" or unfired shape. The porous matrix may also be formed by a bisque firing that does not fully densify the uranium dioxide arrangement 10.

As will be understood by one of ordinary skill in the art, the processes disclosed at page 3, line 34, to page 4, line 3, of the specification will result in an arrangement, comprising the porous uranium dioxide recited in the present claims.

In addition, the recitation in claim 1 of infiltrating the porous uranium dioxide with a precursor liquid, and then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, is supported by the present specification at page 4, lines 23 to 27, where the present specification teaches

> After the precursor liquid 12 has contacted the uranium dioxide arrangement 10 and been incorporated into the matrix of the arrangement 10, at least partially, the arrangement 10 may then be cured. Curing 14 may be through placement of the uranium dioxide arrangement 10 into a furnace 16 between, for example, 180 degrees centigrade and 400 degrees centigrade.

Thus, in light of the present specification, those skilled in the art will understand that the precursor liquid is first infiltrated into the porous uranium dioxide, and then, following the infiltration process, the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, is cured.

In contrast to the presently claimed invention, GB'789 discloses low gas permeability, graphite matrix, nuclear fuel bodies and methods for making such graphite matrix, nuclear fuel bodies. GB'789, page 1, lines 12 to 16. The disclosed method for making the solid, graphite matrix, high temperature nuclear fuel bodies includes the step of coating individual nuclear fuel particles with a protective layer of pyrolytic carbon, such that each of the fuel particles is wholly enclosed in a protective pyrolytic carbon coating. The carbon coated fuel particles are then dispersed substantially uniformly within a matrix of finely divided graphite, which is compacted to a solid fuel body. A portion of the pores of the graphite fuel body are impregnated with a polymerizable substance, which

is then cured and carbonized. The resulting fuel body has low gas permeability, and comprises a plurality of nuclear fuel particles, each of which is wholly enclosed in a protective pyrolytic carbon coating, a graphite matrix in which the particles are uniformly dispersed, and a cured, carbonized and partially graphitized substance that fills a substantial portion of the pores within a distance of at least one eighth of an inch of the surface of the fuel body, such that the fuel body has a substantially reduced gas permeability, compared with that of a non-impregnated graphite body. GB'789, column 1, lines 17 to 49.

Thus, GB'789 provides a solid, high temperature nuclear fuel body for use in a nuclear reactor at temperature in excess of about 1000°C. GB'789, page 2, lines 25 to 30. The disclosed fuel body "can be directly incorporated into a high temperature nuclear reactor of the HTGR or other type and is capable of substantially retaining gaseous fission products at temperatures in excess of 1000°C over extended periods of time." GB'789, page 5, lines 87 to 91, as cited in the Office Action. As will be understood by those skilled in the art, in contrast to the statement in the Office Action at page 5, the reference to "other type" of nuclear reactors refers to high temperature reactors only. Those skilled in the art will know that high temperature reactor fuel cannot be used in light water reactors. Therefore, the process disclosed in GB'789 does not and cannot provide the light water reactor fuel produced with the presently claimed method. Thus, GB'789 does not disclose or suggest the presently claimed invention.

As will be understood by one of ordinary skill in the art, the fuel produced with the process disclosed by GB'789 can only be used in a reactor of the type that operates with graphite matrix nuclear fuel bodies. GB'789, page 1, line 14 and 15; page 2, lines 20 to 25. As is well known to those skilled in the art, reactors that use graphite matrix nuclear fuel bodies operate at temperature in excess of 1000°C. GB'789, page 1, lines 57 to 60. As will be further understood by those skilled in the art, such high temperature reactors are gas cooled reactors. As used by those skilled in the art, the term "HTGR" stands for High Temperature Gas-cooled Reactor.

Those skilled in the art also know that the fuel used in a gas-cooled reactor, i.e., a high temperature reactor, is fundamentally different from the fuel used in a light water reactor. In a gas-cooled reactor, thousands of micro-fuel particles, which are uranium oxide fuel kernels coated with a layer or layers, are dispersed in a pebble or compact graphite matrix. In contrast, the fuel used in a light water reactor comprises millimeter sized pellets of uranium oxide ceramic, loaded in a metallic cladding. Those skilled in the

art will clearly understand that it is impossible to use fuel for a gas-cooled high temperature reactor in light water reactor, and that it is impossible to use fuel for a light water reactor in a gas-cooled high temperature reactor. High temperature reactors require a graphite matrix as a moderator. Light water reactors will not function with the graphite matrix.

Thus, as will be understood by those skilled in the art, the fuel bodies disclosed in GB'789 and the individual particles of nuclear fuel that are each wholly enclosed in a pyrolytic carbon coating used in the fuel bodies disclosed in GB'789 are not the presently claimed porous uranium dioxide.

In particular, one of ordinary skill in the art will understand that individual coated particles of nuclear fuel are not porous. Thus, as GB'789 teaches that individual fuel particles are coated with pyrolytic carbon and dispersed in a finely divided matrix, one of ordinary skill in the art would have no reason to provide an arrangement, comprising porous uranium dioxide, infiltrating the porous uranium dioxide with a precursor liquid, and then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, as presently claimed. Therefore, GB'789 does not disclose or suggest the presently claimed invention.

The other cited references do nothing to overcome the deficiencies of GB'789. Each of the other cited references is directed to a graphite article and/or high temperature reactor fuel. Thus, the other cited references fail to disclose or suggest the presently claimed method for preparing uranium dioxide fuel in pellet shape for use in a light water reactor, and fail to provide any reason why one of ordinary skill in the art would modify the disclosure of GB'789. Although the fissile material of the fuels disclosed in the cited references is the same as that of the presently claimed method, i.e., uranium, the form of the fuel is different, as described above. In addition, the moderator, coolant, and operating conditions are all different. As discussed above, high temperature reactors use fuel particles embedded in a graphite moderator, which is a form that cannot be used in light water reactors. High temperature reactors also use a gas, such as helium, as a coolant, rather than the water of a light water reactor, and operate at a temperature of at least 1000°C at low pressure in contrast to the low temperature, i.e., about 200°C to about 350°C, of light water reactors, which, for pressurized water reactors, can operate at a pressure of about 155 bar.

Therefore, the other cited references, whether taken alone or in combination or in combination with GB'789 do not disclose or suggest the presently claimed invention, and

fail to provide any reason to modify the disclosure of any of the cited references to obtain the presently claimed invention.

Carley-Macauly discloses that uranium carbide and uranium oxide are nuclear fuels. One of ordinary skill in the art, combining the disclosure of Carley-Macauly with that of GB'789 would coat individual nuclear fuel particles of uranium carbide or uranium oxide with a protective layer of pyrolytic carbon, such that each of the fuel particles was wholly enclosed in a protective pyrolytic carbon coating, disperse the carbon coated fuel particles within a matrix of finely divided graphite, compact the matrix to a solid fuel body, impregnate a portion of the pores of the fuel body with a polymerizable substance, and then cure and carbonize the impregnated compacted matrix. That is not the presently claimed invention.

The combination of GB'789 and Carley-Macauly does not disclose or suggest providing an arrangement, comprising porous uranium dioxide, infiltrating the porous uranium dioxide with a precursor liquid, and then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, as presently claimed. Therefore, GB'789 and Carley-Macauly, whether taken alone or in combination, do not disclose the presently claimed invention.

The Office Action also cites Carley-Macauly in combination with Nicholson and Mysels. Applicants respectfully submit that that combination of references also fails to disclose or suggest the presently claimed invention. As discussed above, the presently claimed invention requires providing an arrangement, comprising porous uranium dioxide, infiltrating the porous uranium dioxide with a precursor liquid, and then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid. This allows the precursor liquid to penetrate the entire body of the fuel arrangement so that the resulting second phase, after thermal firing, penetrates to the center of the pellet, thereby producing a uniform overall fuel product. Present specification, page 6, lines 13 to 15.

As will be understood by those skilled in the art, curing the arrangement, comprising the porous uranium oxide and the precursor liquid during the infiltration of the porous uranium dioxide with the precursor liquid would cause blockage of the pores of the uranium dioxide before the entire body of the porous uranium dioxide was infiltrated by the precursor liquid, resulting in an undesirable decrease in the thermal conductivity of the fuel.

In contrast to the presently claimed invention, as disclosed at column 1, lines 20 to 30, Carley-Macauly discloses placing an artifact, having high open porosity and low thermal conductivity, in an atmosphere of hydrocarbon gas. While the artifact is in the atmosphere of hydrocarbon gas, an initial zone of the artifact is heated to a temperature at which carbon is deposited from the gas permeating the artifact to impregnate fully the initial zone. The temperature of the impregnated zone is then raised progressively to maintain the temperature within an advancing impregnated/non-impregnated boundary zone, and the rate of the rise in temperature in the initial zone is being limited, so that the advancing boundary zone is fully impregnated.

As will be understood by those skilled in the art, as the hydrocarbon gas is carbonized and deposited in the artifact in the process disclosed by Carley-Macauly, additional hydrocarbon gas will infiltrate the artifact. This results from the placement of the artifact in the hydrocarbon gas. Curing an artifact placed in an atmosphere of a hydrocarbon gas, such that the gas infiltrates the artifact as the artifact is heated, i.e., cured, is not the presently claimed invention.

Carley-Macauly does not disclose or suggest providing an arrangement, comprising porous uranium dioxide, infiltrating the porous uranium dioxide with a precursor liquid, and then curing the arrangement, comprising the porous uranium dioxide infiltrated with the precursor liquid, as presently claimed.

Nicholson does nothing to overcome the deficiencies of Carley-Macauly. As cited in the Office Action, Nicholson discloses that a refractory body, having an intercommunicating network of pores, can be rendered less porous and more dense by depositing carbon, silicon, or silicon nitride or carbide in the pores of the body. At column 6, lines 10 to 22, as cited by the Office Action, Nicholson discloses

> In a similar manner, substantially any refractory body, that has an intercommunicating network of pores, can be rendered less porous and more dense; either by siliconizing by heating in the presence of silicon nitride above the decomposition temperature of silicon nitride and in an inert atmosphere; or by loading the pores with carbon by any available technique, and then releasing free silicon to react with the carbon, according to this invention. Among the known ways of depositing carbon in the pores, there can be mentioned the resin impregnation and carbonizing process described above; pyrolysis of methane and other hydrocarbons; and impregnation of the shape with furfural or the like, followed by carbonization by acidification.

Therefore, Nicholson clearly teaches that pyrolysis of methane and other hydrocarbons is equivalent to other methods of depositing carbon in a porous body. As the deposition methods are equivalent, those skilled in the art would understand that none of the disclosed methods has any particular advantage over any of the other disclosed methods. That is, a resin impregnation and carbonizing process or a process of impregnation of the shape with furfural or the like has no particular advantage over the pyrolysis of a hydrocarbon, as disclosed by Carley-Macauly. Therefore, one of ordinary skill in the art, following the teaching of Carley-Macauly and Nicholson would have no reason to modify the disclosure of Carley-Macauly.

In addition, replacing the hydrocarbon gas disclosed by Carley-Macauly with a liquid or solid material that is then carbonized would impermissibly change the function of the process disclosed by Carley-Macauly. The hydrocarbon gas disclosed by Carley-Macauly functions in a manner significantly different from that of a liquid or solid material. A hydrocarbon gas will continue to infiltrate the pores of the artifact disclosed by Carley-Macauly as the artifact is heated. A liquid or solid will not. Thus, the process disclosed by Carley-Macauly must be changed significantly to replace the hydrocarbon gas with a liquid or solid. This is not permitted in an obviousness analysis. See M.P.E.P. §§ 2143.01 (V) and (VI).

Thus, one of ordinary skill in the art, following the disclosures of Carley-Macauly and Nicholson would not modify the disclosure of Carley-Macauly. Instead, those skilled in the art would follow the disclosure of Carley-Macauly, and would place the artifact, having high open porosity and low thermal conductivity, in an atmosphere of hydrocarbon gas, and, while the artifact was in the atmosphere of hydrocarbon gas, heat an initial zone of the artifact to a temperature at which carbon is deposited from the gas permeating the artifact to impregnate fully the initial zone. Curing an artifact placed in an atmosphere of a hydrocarbon gas, such that the gas infiltrates the artifact as the artifact is heated, i.e., cured, is not the presently claimed invention.

Therefore, Carley-Macauly and Nicholson, whether taken alone or in combination, do not disclose or suggest the presently claimed invention.

Mysels does nothing to overcome the deficiencies of Carley-Macauly and Nicholson. As cited in the Office Action, Mysels discloses that carbon can be deposited in the pores of a fuel element by placing a phenol-formaldehyde prepolymer or furfuryl alcohol monomer/prepolymer into the pores of the fuel element, curing the prepolymer, and then decomposing the cured polymer.

However, as discussed above, Nicholson clearly teaches that pyrolysis of methane and other hydrocarbons is equivalent to other methods of depositing carbon in a porous body, including resin impregnation and impregnation with furfural or the like. One of ordinary skill in the art would understand from the teaching of Nicholson that using any of the other disclosed methods of depositing carbon had any particular advantage over the pyrolysis of a hydrocarbon. Therefore, Nicholson and Mysels provide no reason for one of ordinary skill in the art to modify the disclosure of Carley-Macauly.

One of ordinary skill in the art, following the disclosures of Carley-Macauly, Nicholson, and Mysels would not modify the disclosure of Carley-Macauly. Instead, those skilled in the art would follow the disclosure of Carley-Macauly, and use the process disclosed by Carley-Macauly. Again, curing an artifact placed in an atmosphere of a hydrocarbon gas, such that the gas infiltrates the artifact as the artifact is heated, i.e., cured, is not the presently claimed invention. Therefore, Carley-Macauly, Nicholson, and Mysels, whether taken alone or in combination, do not disclose or suggest the presently claimed invention.

GB'789 does nothing to overcome the deficiencies of Carley-Macauly, Nicholson, and Mysels. Repeating the steps disclosed by those references will not provide the presently claimed invention. Therefore, Carley-Macauly, Nicholson, Mysels, and GB'789, whether taken alone or in combination, do not disclose or suggest the presently claimed invention.

Burnham does nothing to overcome the deficiencies of GB'789, Carley-Macauly, Nicholson, and Mysels. As cited in the Office Action, Burnham discloses a fuel element that comprises a dense body consisting essentially of uranium carbide, graphite, silicon carbide, and silicon. At column 1, lines 47 to 59, Burnham discloses that the disclosed fuel element is formed as follows:

> A quantity of graphite bonded uranium carbide, preferably containing about 30% or more by weight uranium and the remainder carbon, is pulverized to a grain size of from 40 mesh to 200 mesh. The resulting granular product is then mixed, either alone or preferably in combination with a quantity of silicon carbide grain, with a phenol formaldehyde or other suitable resin binder. This mixture is then cold or hot pressed to the desired shape and heated in a suitable atmosphere to cure the resin drive off the volatiles.

Therefore, Burnham discloses a fuel element containing silicon carbide that is prepared by mixing granular uranium carbide, and silicon carbide, and then pressing and heating the

resulting mixture. Burnham fails to disclose or suggest any method of introducing silicon carbide into a porous body, or any reason one of ordinary skill in the art would replace the carbon deposited in the methods disclosed by GB'789 and Carley-Macauly with silicon carbide. The only method disclosed by Burnham requires the mixing of granular uranium carbide fuel and granular silicon carbide. As will be clearly understood by one of ordinary skill in the art, the method disclosed by Burnham cannot be used in the method of GB'789 or the method of Carley-Macauly to reduce the gas permeability of a fuel element.

Even if one of ordinary skill in the art combined the disclosure of Burnham with those of any or all of GB'789, Carley-Macauly, Nicholson, and Mysels, the resulting combination would not provide the presently claimed invention. Instead, the combination would provide the method of either GB'789 or Carley-Macauly in which the gas permeability of a fuel element containing granular silicon carbide was reduced. As discussed above, those methods are not the presently claimed invention. Burnham, GB'789, Carley-Macauly, Nicholson, and Mysels, whether taken alone or in combination do not disclose the presently claimed invention.

Chayka does nothing to overcome the deficiencies of GB'789, Carley-Macauly, Nicholson, Mysels, and Burnham. As cited in the Office Action, Mysels discloses that a liquid allylhydridopolycarbosilane is a commercially available silicon carbide source that is in the art. However, as discussed above, one of ordinary skill in the art, following the disclosures of GB'789, Carley-Macauly, Nicholson, Mysels, and Burnham would mix granular silicon carbide with uranium carbide to obtain a fuel element. That is not the presently claimed invention, and GB'789, Carley-Macauly, Nicholson, Mysels, Burnham, and Chayka, whether taken alone or in combination, do not disclose or suggest the presently claimed invention.

As GB'789, Carley-Macauly, Nicholson, Mysels, Burnham, and Chayka, whether taken alone or in combination, do not disclose or suggest the presently claimed invention, the present claims are not obvious. Accordingly, it is respectfully requested that the Examiner withdraw the rejections of the claims under 35 U.S.C. § 103(a) over Chayka, GB'789, Carley-Macauly, Nicholson, Mysels, and Burnham.

Applicants thus submit that the entire application is now in condition for allowance, an early notice of which would be appreciated. Should the Examiner not agree with Applicants' position, a personal or telephonic interview is respectfully requested to discuss any remaining issues prior to the issuance of a further Office Action, and to expedite the allowance of the application.

A separate Petition for Extension of Time is submitted herewith. Should any other fees be due, however, please charge such fees to Deposit Account No. 11-0600.

Respectfully submitted,
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Dated: March 5, 2008

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